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243 CHARLES STREET

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THE prime purpose of the Howe Laboratory is basic research pertaining to the eye and a report of the years activities is devoted largely to specific accomplishments in this field. Not to be overlooked, however, are the less tangible contributions made by the Laboratory group to diverse ends; that pertaining to postgraduate education is especially noteworthy this year and will be considered separately.

Research

With the ultimate aim of correlating aqueous humor formation with intraocular pressure, Dr. V. Everett Kinsey and co-workers have obtained further valuable data on several factors involved. Especially studied has been the biochemistry of ascorbic acid which, as noted in previous reports, appears to be an index of the intraocular secretory process. One degradation product of ascorbic acid, not previously recognized, has been isolated in pure form (furoic acid), and the presence of several others has been indicated by analysis with ultra-violet spectroscopy. The partition of chlorides between blood and aqueous has also been further investigated. Contrary to findings elsewhere, those in the Howe Laboratory have shown that the chloride content of the aqueous humor does not so greatly exceed that of the blood that it is necessary to postulate the presence of additional positive ions to keep the aqueous humor electrically neutral. Moreover, it suggests that the reported osmotic pressure differences between aqueous humor and blood cannot be accounted for on the basis of chlorides alone. Measurements of the osmotic pressure of the aqueous humor and of the blood are of course of critical significance, but there is some doubt as to the validity of comparing the osmotic pressure of a fluid like plasma, which contains a large amount of protein, with that of aqueous humor which is practically free of protein. An apparatus employing a new amplifying system has been assembled and preliminary measurements have been made on salt solutions containing known amounts of crystalline plasma.

In this comprehensive study of factors involved in aqueous humor formation by Dr. Kinsey, the rate of penetration of amino acids and analogous substances has been investigated by Dr. Mary Amdur, and of alcohols having various molecular weights by Dr. Arnold Forrest. In the case of the amino acids it has been found, thus far, that the rate of transfer of a compound into the aqueous humor from the blood is independent of the charge on the molecule. In the case of the alcohols it has been found that the rate of transfer is compatible with a process of simple diffusion. One of the chief objectives of these studies has been to determine the factors which are responsible for intraocular pressure. The experimental findings obtained thus far indicate that the intraocular pressure is due to the sum of the hydrostatic pressure from the capillaries and the osmotic pressure difference between the blood and aqueous. The latter in turn depends upon the rate of secretion, the permeability of the blood aqueous barrier and the rate of flow from the eye.

Poisoning of the eye and optic nerve with methyl alcohol has been the starting point of many investigations but the mode of action of this agent has never been satisfactorily elucidated. Dr. W. Morton Grant has, however, made several important observations on the intermediate products of methyl alcohol metabolism in rabbits. It was found that, unlike ethyl alcohol and its oxidation product, acetaldehyde, which may condense with pyruvic acid in vivo, methyl alcohol and formaldehyde formed no analogous condensation product with pyruvic acid. To determine whether or not the damage to the eye may result from the formaldehyde formed from methyl alcohol, extensive investigations have been conducted on the toxicity of formaldehyde, its rate of formation in the body from methyl alcohol, and its reactivity with plasma and tissue proteins. Incidental to these studies, Dr. Grant has developed a second and more specific micromethod for measurement of formic acid in tissue.

Two new agents for the treatment of glaucoma have been submitted to laboratory and clinical investigation by Dr. Grant. One of these substances, hexaethyl tetraphosphate, has previously been in use as an insecticide (known as Bladan in Germany). The ocular symptoms reported in human beings following the absorption of this substance through the skin suggested a potential usefulness of the compound in treatment of glaucoma. The second substance, tetraethyl pyrophosphate, the component of the commercial insecticide having the greatest biological activity and available in purest form, is known to have anticholinesterase activity similar to eserine and di-isopropylfluorophosphonate which have previously been employed in treatment of glaucoma. Tetraethyl pyrophosphate was found also to be effective in control of glaucoma but to share some of the disadvantages of the other anticholinesterase drugs.

A review of the biochemistry, pharmacology, and toxicology literature pertaining to the eye for the years 1944–1946 was prepared by Drs. Grant and Cogan based on the bibliography prepared by Dr. Grant in the previous year. This is to comprise a chapter in a forthcoming book on recent advances in ophthalmology and is a companion to the volume noted in the Annual Report of 1944.

The studies noted previously on the variation of visual acuity with movement of the object, has been investigated further by Dr. Elek Ludvigh. The limiting factor with high angular velocity of the object appears to be the ability to move the eye with sufficient precision to maintain fixation during the movement. A potentially important sidelight of these investigations is the discovery that the amount of illumination optimal for observation of moving objects is much higher than that for stationary objects.

By exposing Landolt rings for fractions of a second, Dr. Ludvigh has found that visual acuity varies linearly with the logarithm of exposure time. Acuity is not appreciably improved by exposures for more than about one second. On the other hand alignment sense and direction sense are improved by several seconds exposure; from this it may be inferred that these latter functions require elaboration at a higher level in the nervous system.

The continuation of studies on the light difference sense in amblyopia ex anopsia has shown that the light difference sense of the affected eye may be normal although the visual acuity is markedly reduced. This finding would appear to indicate that the classical hypothesis of the dependence of visual acuity on light difference sensitivity is insecure.

Modern hypotheses attempting to account for the high accuracy of the "position sense" as exhibited in stereoscopic and alignment tests rely chiefly on a statistical averaging of numerous cones to produce the perception of position. However, Dr. Ludvigh's investigations of what may be called the "direction" sense have indicated that a dot may be placed in the direction indicated by a line with extreme accuracy (2 seconds of arc) although the dot did not stimulate any large number of cones as hypotheses of the statistical type require.

A quantitative evaluation of projection campimetry in comparison with other methods was undertaken by Dr. Ludvigh and Dr. Albert S. Biegel. Reproducibility of blind spots and field defects, as well as maintainance of fixation, were found superior with the projection methods. An especial advantage of the projection type of campimetry is the ease with which the illumination of the test object, and therefore its contrast value with the background, may be continuously varied during the testing. It was also noted that large, low contrast test objects are much more resistant to the effects of refractive errors and ocular opacities than is the case with the small high contrast test objects commonly employed.

The color characteristics of papers commonly employed in field testing have recently been analyzed by Dr. Ludvigh and Dr. Garrett Sullivan. The colors were found to differ greatly in brightness and saturation and were not psychological primaries.

For the past several years observations have been made on the opticokinetic response of patients with a variety of intracranial lesions. The data on these patients has now been reviewed by Drs. David G. Cogan and Donald Loeb with the aim of assessing its value in neuro-ophthalmic examination. Asymmetry of the opticokinetic response was found to be a reliable index for lateralizing the lesion in patients with unilateral cerebral disease, being most evident, and therefore most useful, when the lesion was situated in the middle or posterior portions of the hemisphere. The response was, however, variable and therefore of little value, in patients with lesions of the brain stem or cerebellum.

Together with Dr. Fuller Albright, Dr. Cogan has, during the past year, observed eight patients who were unusual in having an abortive band keratitis associated with an elevated blood calcium. The hypercalcemia was variously due to hyperparathyroidism, sarcoidosis, and excessive intake of vitamin D. The pathogenesis of the band keratitis and its relation to the hypercalcemia is currently being studied.

The possibility that a study of retinal vascular accidents in hypertensive patients might yield information of value in an understanding of the hypertensive process is being explored by Drs. Cogan and Loeb. The retina is the only place in the body where the blood vessels may be examined readily on the flat. It is a possibility that a topographic visualization of the accidents such as is not feasible anywhere else in the body may yield valuable information. Accordingly the data is being analyzed on approximately 35 patients who have in the past few years been observed to have retinal vascular accidents. It is obvious that there are two types of accidents, those characterized by occlusion of the vein and those characterized by occlusion of the artery. The relation of these two types to other retinal and systematic signs is the object of the present study.

Each year many new drugs are introduced into ophthalmic use. Most drugs make their debut through the publication of results obtained by some enthusiastic protagonist with little regard to drugs already available for that particular purpose. Dr. Cogan and Dr. Grant are, therefore, undertaking a quantitative comparison of one group of drugs, the anticholinesterases, with the intention of establishing the crucial factors involved in evaluating the relative merits of ophthalmic drugs, and thereby providing a standard for subsequent comparisons.

Infection with the herpes simplex virus, considered relatively innocuous in general medicine, occupies a serious place in ophthalmology because of the serious scarring of the cornea which it often induces. There is little doubt that effective means for the treatment of keratitis caused by this organism would be a major discovery. The present treatment, developed by Dr. Gundersen several years ago in the Howe Laboratory, consists of an iodine scrub of the cornea. While this is the best form of treatment to date, it is far from ideal. It was hoped that the use of concentrated antibodies in pooled solutions of gamma globulin might prove to be a better form of therapy. Accordingly, Dr. Henry F. Allen, together with members of the Bacteriology Department of the Harvard Medical School, investigated the neutralizing effect of serum gamma globulin on the virus, herpes simplex (and on the viruses of lymphocytic choriomeningitis and epidemic keratoconjunctivitis). By the protection afforded mice innoculated with the virus it was found that stock gamma globulin obtained from pools collected by the Red Cross did consistently contain antibodies in sufficient concentration to inactivate the virus herpes simplex (but not the virus of lymphocytic choriomeningitis nor of epidemic keratoconjunctivitis). The possible therapeutic implications of this were tested by the intraperitoneal injection of the gamma globulin into mice at intervals before and after inoculation of the animals with the virus. Considerable protection was afforded when the antibodies were given within the first two days after the inoculation, but the protection became rapidly less on the third day even with massive doses. Nor did local instillation of the gamma globulin on the eye have an appreciable effect on the experimental keratitis three days or longer after the inoculation, that is, at a time when the virus had become intraepithelial. Since herpetic keratitis in human beings does not become manifest for three or four days after the inoculation, this form of treatment would appear to have little promise.

Iontophoresis is well established as a means through which charged chemical particles are introduced into the body tissues by an electric current. In ophthalmology, iontophoresis has recently been widely advocated to obtain high concentrations of sulfonamides and penicillin into the eye in order to combat intraocular infections. Yet the mechanism by which iontophoresis acts on the eye has never been subjected to a comprehensive study. Indeed previous investigations in the Howe Laboratory showing that the normal cornea was impermeable to ions and offered a high resistance to the passage of an electric current would suggest that it is not a suitable membrane for iontophoresis. Accordingly, the problem is being currently investigated by Dr. Charles Dyson with the aim of determining what the barrier properties of the cornea are to iontophoresis and, it is hoped, what are its therapeutic possibilities.

The surgical treatment of separated retina is one of the crudest of procedures in ophthalmic surgery and its results are the least predictable. In an attempt to refine our present methods Dr. Charles L. Schepens is currently making an exhaustive study of selected patients preoperatively and postoperatively with special attention to the operative procedures. Along with this survey Dr. Schepens is making extensive use of a specially constructed ophthalmoscope and a self-luminous electrode which he had designed before joining the Laboratory.

TEACHING

Aside from a large amount of instruction which the Howe Laboratory group both gives and receives on an informal plane, there are three formal levels of teaching in which the Howe Laboratory group participates: the teaching of undergraduate medical students, the teaching of postgraduate students who are preparing for the practice of ophthalmology, and the teaching and training of certain Fellows in research.

Of the three the teaching of undergraduate medical students is of the least concern to the Howe Laboratory since this is carried on by the Department of Ophthalmology. However, it is worth mentioning that Dr. Grant lectured and assisted in laboratory exercises in pharmacology of the eye for the undergraduates and Dr. Cogan similarly lectured and assisted in the laboratory exercises on the pathology of the eye.

The teaching of postgraduate students on the other hand has been a major preoccupation of the Howe Laboratory staff for the past several years. The present three months course in the Basic Sciences of Ophthalmology was organized nine years ago by Dr. Cogan, at the suggestion of Dr. J. Herbert Waite, and the teaching of it has been done largely by the Howe Laboratory staff with the administrative assistance and moral support of Dr. Edwin B. Dunphy. This is believed to be the first course of its kind devoted entirely to the basic sciences in ophthalmology and has served well its purpose of raising the standards of ophthalmic education. In response to requests from institutions planning to set up analogous courses elsewhere, a detailed description of the Harvard Course has recently been published in the *Archives of Ophthalmology*. Following this description is an interesting commentary by leaders in various ophthalmic centers throughout the country. Not all agree that the Harvard Course is ideal and several present suggestions for specific improvements. But the interesting implication is given that the teaching of basic sciences must be a part of the training of the future ophthalmologist and the limiting factor in such teaching is the availability of a staff who have had contact with first hand research on eye problems. The article, and especially the subsequent discussion, merits reading by all who are seriously interested in ophthalmic education.

The specific assignments of the Howe Laboratory group in the aforementioned course are as follows: Physiologic Optics, Dr. Ludvigh; Biochemistry and Physiology of the Eye, Dr. Kinsey; Pharmacology, Toxicology, and Introduction to Clinical Procedures, Dr. Grant; and Neuro-ophthalmology, Dr. Cogan. In a somewhat similar course now being conducted by the American Board of Ophthalmology, Dr. Kinsey also gave a series of lectures on Biochemistry of the Eye and Dr. Cogan gave a series of lectures and supervised laboratory exercises on Pathology of the Eye. As a result of this teaching, various articles have been published by the staff on didactic methods and technique as well as one text book.

The teaching and training of Fellows in research is much in the foreground now, much more than ever before and probably more than it will be a few years hence. The Howe Laboratory policy and problems which such training entails were cited in last year's report. Little progress has been made in obtaining proper space but the importance of having such Fellows has seemed so great that they have been crowded into the existing quarters. Those who completed their Fellowship during the past year were Drs. Albert C. Biegel and Henry F. Allen. New appointees and their sponsors were: Dr. Mary Amdur, Snyder Foundation; Dr. Charles Dyson, Medical Research Council of Canada; Dr. Arnold Forrest, National Cancer Institute; Dr. Charles L. Schepens, Vivian B. Allen Foundation and American Optical Company. Dr. Forrest left after six months to join a cancer research project elsewhere. Also in the Howe Laboratory group during the past year but not appointed as Fellows since their tenure was less than one year were Dr. Robert R. Trotter and Dr. Rush M. Blodget, Jr. Under the sponsorship of the Medical Research Council of Sweden Dr. Ernst

Bárány of Upsala University has elected to join the Howe Laboratory group for six months study and research.

Despite the whole hearted endorsement of teaching by the Howe Laboratory staff, there are real dangers in so straddling a department with such teaching loads that research is stifled. It is, therefore, with considerable satisfaction and relief from the Laboratory's point of view that Dr. Parker Heath joined the Harvard Medical School faculty during the past year for the express purpose of supervising postgraduate teaching. The Howe Laboratory staff continued to do much of the teaching in the Basic Science Course but the administration was carried on by Dr. Heath.

OTHER ACTIVITIES

Under this heading may be listed a group of activities which are, strictly speaking, neither "Research" nor "Services Rendered" but are potentially both. These are the activities that make for much mutual profit between the Howe Laboratory, the hospital and other organizations.

For the first half of the past year, the Pathology Department of the Massachusetts Eye and Ear Infirmary was operated by Dr. Cogan with the frequent and indispensable counsel of Dr. Frederick H. Verhoeff. Dr. Cogan has been continued as Director of the Ophthalmic Laboratories but Dr. Parker Heath has now taken over completely the operation of the Pathology Department.

For photography of the eye, Drs. Robert R. Trotter and W. Morton Grant have developed an illuminating system that is considerably superior to any previously employed. The source of light is an electronic flash bulb of the Edgerton type. The intensity of the light is so great as to permit small diaphragm stops of the camera and the duration of the flash (1/10,000 sec.) is so short as to make movements of the eye during photography inconsequential and at the same time to minimize the apparent brightness to the patient.

A start toward developing a file of photomicrographs was made by Dr. Rush M. Blodget, Jr. This file has already been most useful in the teaching of pathology.

As an ex officio consultative service Dr. Cogan and Dr. Grant have continued active participation in seeing such patients of the Eye and Ear Infirmary and of the Massachusetts General Hospital as are referred by the respective staffs. Most of these patients present merely diagnostic problems, but many are of considerable research interest. Especially active is the participation with the Thyroid, Hypertensive and Neurologic services. Dr. Kinsey has continued to act as consultant for the Massachusetts Eye and Ear Infirmary in the study of retrolental fibroplasia and has directed the experimental research in the project.

During the past year the Howe Laboratory group held an all day meeting for ophthalmic investigators outside of Boston. Various projects presently being studied at the Laboratory were presented and discussed. This is the first of the informal interurban conferences held since the termination of the war. Dr. Cogan and Dr. Frederick H. Verhoeff, director-emeritus of the Howe Laboratory, also participated during the past year in a two day meeting of ophthalmic pathologists at the Army Institute of Pathology in Washington.

The Lucien Howe Library under the direction of Miss Jeanette Loessl has served well the ophthalmic and general medical community. Aside from the routine functions, Miss Loessl has prepared several bibliographies, translated many articles, done considerable proof reading, tracked down numerous references and scanned the current literature for articles pertaining to the projects of the staff. The Howe Library has continued to serve as a clearing house for ophthalmological journals sent abroad. The demand from overseas exceeds the supply and further contributions, especially of the wartime journals, were again solicited in this country.

Support of the Laboratory

Increased costs with a fixed capital having a no more than average yield is a plight common to all endowed institutions. The remarkable thing is that the Laboratory has been able to maintain its pre-inflation size and productivity. This has been made possible in part by personal sacrifice on the part of the staff and in part by increments to the income of the Laboratory through several farseeing individuals and institutions. Especially noteworthy are the American Optical Company and the Massachusetts Eye and Ear Infirmary. The American Optical Company has continued its support of physiologic optics in the Laboratory in a most exemplary manner; it should be noted that at no time has any pressure been put on the Laboratory for applied investigations or for specific projects. It is with great satisfaction to record that this contact of the Laboratory with a major industrial company has been entirely satisfactory and not in the least prejudicial to basic research. The Massachusetts Eye and Ear Infirmary has in the past provided space and certain services to the Laboratory but never heretofore has it underwritten other expenses of the Laboratory. Yet it cannot be denied that much of the prestige of the Infirmary in the scientific world is due to the researches in the Howe Laboratory. Accordingly, the trustees of the Infirmary expressed their determination to keep the Laboratory at its present level of operations by making a contribution to offset its deficit. This is more than a gesture of generosity. It is a tangible recognition of the part played by research in a modern hospital. To some of us it is a mark of a progressive hospital.

Of no less importance is the aid from Foundations for specific projects and from individuals for general expenses. It is the continued hope that large additions to the Laboratory's endowment may be made. Such additions would preserve the identity of the donor by being set aside as an appropriately named fund. In lieu of large donations it is gratifying to record the spontaneous donations which were made by individuals for a variety of reasons and purposes. The gesture of a half-blind colored man with glaucoma who brought in four rabbits because the Laboratory took him on as a "special case" is appreciated. Of greater practical importance are several donations from physicians who wish to further the cause which the Howe Laboratory represents. The spontaneity of these donations and the confidence which they imply is a great source of satisfaction. They go a long way toward offsetting the disappointments and failures which are, just as much as the successes, integral parts of operating a research laboratory.

Conclusions

The congeries of persons and things that make up the Howe Laboratory of Ophthalmology bridge in some measure the gap between basic sciences and applied ophthalmology.

The types of researches and diversity of interests bear testimony to this. It is reasonably certain such a union of interests, centering about the eye, will continue to be productive as regards both research and non-research activities.

The following have, by their contributions to the Laboratory fund, made possible the continuation of the Laboratory at its present level.

American Optical Company, for the support of research in physiologic optics (second year of a three year grant).

The Massachusetts Eye and Ear Infirmary, for general expenses.

The John and Mary Markle Foundation, for the support of studies on factors affecting intraocular pressure (second year of a two year grant-in-aid).

The Snyder Foundation, for determination of relative osmotic pressure in blood and aqueous humor.

Vivian B. Allen Foundation, to assist Dr. Schepens in his study on separated retinas.

Paul A. Chandler, M.D., for general expenses.

Frank D. Carroll, M.D., for the study of methyl alcohol poisoning.

William F. Donoghue, M.D., for general expenses.

David G. Cogan, M.D.
Director

LECTURES WHICH WERE GIVEN AND ARTICLES WHICH WERE PUBLISHED DURING 1947

Cogan, D. G. Pathology of the anterior eye. Series of lectures and demonstrations to New England Ophthalmological Society, in Boston, Massachusetts, 1947.

Cogan, D. G. Aims and aids in the teaching of basic sciences in ophthalmology. Arch. Ophth. 37: 428–432, 1947.

Cogan, D. G. Pathology of the eye. Series of lectures and demonstrations at Ophthalmological Study Council, Portland, Maine, July–August, 1947.

Cogan, D. G. Vascular diseases of the fundus. Presented before the Cardiac Section of the American College of Physicians, in Boston, Massachusetts, November 14, 1947.

Cogan, D. G. and Loeb, D. R. The significance of the opticokinetic response with intracranial lesions. Presented at the Massachusetts Eye and Ear Infirmary Alumni Association Meeting, in Boston, Massachusetts, November 17, 1947.

Cogan, D. G. Epibulbar tumors. Presented before the Buffalo Ophthalmological Society, Buffalo, New York, December 11, 1947.

Grant, W. M. Colorimetric micromethod for determination of formic acid. Anal. Chem. 19: 206–207, 1947.

Grant, W. M. Methyl Alcohol Poisoning. Seminar at the Department of Pharmacology, Harvard Medical School, Boston, Massachusetts, March 26, 1947.

Grant, W. M. Colorimetric determination of sulfur dioxide. Anal. Chem. 19: 345–346, 1947.

Grant, W. M. Students' model for slit lamp biomicroscopy of the aqueous humor. Arch. Ophth. 38: 109, 1947.

Grant, W. M. Ophthalmic pharmacology. Two lectures presented in the regular Pharmacology Course of Harvard Medical School, Boston, Massachusetts, December 2 and 4, 1947.

Heyl, J. T., Allen, H. F. and Cheever, F. S. Some immunological reactions of human serum gamma globulin with the viruses of herpes simplex and epidemic keratoconjunctivitis. Presented by Dr. Henry F. Allen at the New England Ophthalmological Society, in Boston, Massachusetts, December 17, 1947.

Kinsey, V. E. and Grant, W. M. Action of mustard gas and other poisons on yeast cells. I. Effect of mustard gas on the rate of cell division. J. Cell. & Comp. Physiol. 29: 51–64, 1947.

Kinsey, V. E. and Grant, W. M. Action of mustard gas and other poisons on yeast cells. II. Effect of mustard gas on the mortality, morphology, carbohydrate metabolism, and permeability. J. Cell. & Comp. Physiol. 29: 65–74, 1947.

Kinsey, V. E. and Grant, W. M. Action of mustard gas and other poisons on yeast cells. III. Distribution of fixed mustard gas in yeast. J. Cell. & Comp. Physiol. 29: 75, 1947.

Kinsey, V. E. and Grant, W. M. Action of mustard gas and other poisons on yeast cells. IV. Study of effects of divinyl sulfone and their reversal. J. Cell. & Comp. Physiol. 29: 95, 1947.

Kinsey, V. E. and Grant, W. M. Action of mustard gas and other poisons on yeast cells. V. Correlation between the quantity of glutathione bound by mustard and divinyl sulfone and their effect on growth rate. J. Cell. & Comp. Physiol. 29: 289–300, 1947.

Kinsey, V. E. and Grant, W. M. Action of mustard gas and other poisons on yeast cells. VI. Study of the relationship between inhibition of carbohydrate metabolism and inhibition of growth by various poisons, and effects of other toxic agents on yeast. J. Cell. & Comp. Physiol. 30: 31–42, 1947.

Kinsey, V. E. Some observations on the role of vitamin C in aqueous humor formation. Presented at the Massachusetts General Research Council Meeting, in Boston, Massachusetts, March 25, 1947.

Kinsey, V. E. Fundamental research in the clinical specialties. Science 105: 373, 1947.

Kinsey, V. E. Biological aspects of mustard gas. Presented at the Department of Biology, Harvard University, Boston, Massachusetts, April 25, 1947.

Kinsey, V. E. The chemistry of ascorbic acid and its relation to aqueous humor. Presented at the Department of Chemistry, Harvard University, Boston, Massachusetts, April 28, 1947.

Kinsey, V. E. Transfer of ascorbic acid across the blood-aqueous barrier. Presented at the Association for Research in Ophthalmology, Atlantic City, New Jersey, June 10, 1947.

Kinsey, V. E. Transfer of ascorbic acid and related compounds across the blood-aqueous barrier. Am. J. Ophth. 30: 1262, 1947.

Kinsey, V. E. Use of radioactive isotopes in ophthalmic research. Presented at the New England Ophthalmological Society, in Boston, Massachusetts, November 18, 1947.

Ludvigh, E. J. Visibility of the deer fly in flight. Science 105: 176–177, 1947.

Ludvigh, E. J. Bench for the teaching of ophthalmic optics. Arch. Ophth. 37: 383–385, 1947.

Ludvigh, E. J. in collaboration with Gallagher, J. R., Martin, S. F. and Gallagher, C. D. Effect of training methods on color vision. Arch. Ophth. 37: 572–582, 1947.